International Journal of

Rock Mechanics and Mining Sciences

Volume 31 1994

List of Contents and Author Index

Editor-in-Chief:
J. A. Hudson, Imperial College, London, UK

Pergamon

Rock Mechanics and Mining Sciences

Editor-in-Chief

Professor J. A. Hudson
7 The Quadrangle, Welwyn Garden City,
Herts AL8 6SG, U.K.

Associate Editor

Mrs C. Hudson
7 The Quadrangle, Welwyn Garden City,
Herts AL8 6SG, U.K.

Editorial Advisors

Professor E. T. Brown
Faculty of Engineering, University of Queensland, St Lucia, Queensland 4072, Australia.
Professor N. G. W. Cook
Department of Materials Science and Engineering, University of California, Hearst Mining Building, Berkeley, CA 94720, U.S.A.
Professor C. Fairhurst
Department of Civil Engineering, 122 Civil Engineering Building, 500 Pillsbury Drive S.E., University of Minnesota, Minneapolis, MN 55455-0220, U.S.A.
Professor R. E. Goodman
Department of Civil Engineering, University of California, Davis Hall, Berkeley, CA 94720, U.S.A.
Professor E. Hoek
West Broadway Professional Centre, 412-2150 West Broadway, Vancouver, BC, Canada V6K 4L9.
Professor N. R. Morgenstern
Department of Civil Engineering, University of Alberta, Edmonton, Alberta, Canada T6G 2E1.

Editorial Board

Professor G. Barla
Department of Structural Engineering, Technical University (Politecnico) of Turin, Corso Duca degli Abruzzi 24, 10129 Torino, Italy.
Dr B. H. G. Brady
Department of Mining & Metallurgical Engineering, The University of Queensland, Brisbane, Queensland 4072, Australia.
Dr F. H. Cornet
Institut de Physique du Globe, Université Pierre et Marie Curie, 4 place Jussieu, 75230 Paris Cedex 05, France.
Professor S. L. Crouch
Department of Civil Engineering, 122 Civil Engineering Building, 500 Pillsbury Drive S.E., University of Minnesota, Minneapolis, MN 55455-0220, U.S.A.
Professor Y. D. Diadkin
G. V. Plekhanov Mining Institute, St Petersburg V-26, 21 Liniya 2, Russia.
Professor H. K. Kutter
Ruhr-Universität Bochum, Institut für Geologie, 463 Bochum, Universitätsstrasse 150, Germany.
Dr P. R. La Pointe
Golder Associates Inc., 4104-148th Avenue N.E., Redmond, WA 98052, U.S.A.
Professor W. G. Pariseau
Department of Mining Engineering, University of Utah, 318 W. C. Browning Building, Salt Lake City, UT 84112, U.S.A.
Professor F. F. Roxborough
School of Mining Engineering, University of New South Wales, P.O. Box 1, Kensington, New South Wales 2033, Australia.
Professor K. Sassa
Department of Mining Science and Technology, Faculty of Engineering, Kyoto University, Sakyo-ku, Kyoto 606-01, Japan.
Professor O. Stephansson
Department of Engineering Geology, Royal Institute of Technology, S-100 44 Stockholm, Sweden.
Professor Qiuling Ha
President of Chinese National Group ISRM, Chief Engineer, China Three Gorges Project Development Corp., 443002 Yichang, Hubei, People's Republic of China.
Dr H. Wagner
Chamber of Mines, P.O. Box 809, Johannesburg 2000, South Africa.

Geomechanics Abstracts

Consulting Editor

Dr D. H. Spencer

Editorial Director

Professor J. A. Hudson
Rock Mechanics Information Service
Imperial College of Science, Technology and Medicine
Royal School of Mines, Prince Consort Road
London SW7 2BP, U.K.
Tel. 0171-589-5111 extn 6436
Fax 0171-589-6806
Telex 929484

Geomechanics Abstracts Database

The GeoMechanics Abstracts database (GMA), one of the many available online from the ORBIT Search Service Division of InfoPro Technologies Ltd, covers the fields of rock mechanics, soil mechanics, and engineering geology, plus the many closely related disciplines. GMA is available to the public for literature searching.

For further details please contact the ORBIT Search Service at:

North America
8000 Westpark Drive, McLean, VA 22102, U.S.A.
Tel. (800)45-ORBIT (toll free)/(703)442-0900; *Fax* (703)893-4632

Europe
Achilles House, Western Avenue, London W3 0UA, U.K.
Tel. (0181)992-3456; *Fax* (0181)993-7335; *Telex* 8814614

Australia
P.O. Box 544, Potts Point, NSW 2011, Australia
Tel. (02)360-2691 (direct)/(02)331-5211 (switchboard)/(008)22-6474 (toll free); *Fax* (02)332-2304

Japan
USACO Corporation, 13-12 Shinbashi 1-Chome, Minatoku, Tokyo, 105, Japan
Tel. (03)502-6471; *Fax* (03)593-2709; *Telex* J26274 USACO TOKYO

Published 6 issues/annum in February, April, June, August, October and December

Copyright © 1994 Elsevier Science Ltd

Publishing office: Elsevier Science Ltd, Bampfylde Street, Exeter EX1 2AH, U.K. [*Tel.* (01392) 51558; *Fax* 425370].

Production Editor: Sarah Gooding.

Subscription and advertising offices: Enquiries from customers in North America should be sent to Elsevier Science Inc., 660 White Plains Road, Tarrytown, NY 10591-5153, U.S.A.; and from the Rest of the World to Elsevier Science Ltd, The Boulevard, Langford Lane, Kidlington, Oxford OX5 1GB, U.K. [*Tel.* Oxford (01865) 843000; *Fax* 843010].

Annual subscription rates: Annual Institutional Subscription Rates 1995: North, Central and South America, US$976.00; Rest of the World, £655.00. Associated Personal Subscription Rates are available on request for those whose institutions are library subscribers. Sterling prices exclude VAT. Non-VAT registered customers in the European Community will be charged the appropriate VAT in addition to the price listed. Prices include postage and insurance and are subject to change without notice.

Back issues: Back issues of all previously published volumes, in both hard copy and microform, are available direct from Elsevier Science offices.

Second class postage paid at RAHWAY, NJ. Postmaster send address corrections to *International Journal of Rock Mechanics and Mining Sciences & Geomechanics Abstracts*, c/o Elsevier Science Inc., 660 White Plains Road, Tarrytown, NY 10591-5153, U.S.A.

CONTENTS OF VOLUME 31

NUMBER 1

INDIAN ROCK MECHANICS

Editorial
J. A. Hudson 1

V. M. Sharma and A. K. Dhawan 3 Rock mechanics developments in India

T. Ramamurthy and V. K. Arora 9 Strength predictions for jointed rocks in confined and unconfined states

P. R. Sheorey 23 A theory for *in situ* stresses in isotropic and transversely isotropic rock

C. Mukherjee, P. R. Sheorey and K. G. Sharma 35 Numerical simulation of caved goaf behaviour in long-wall workings

N. K. Sah, P. R. Sheorey and L. N. Upadhyaya 47 Maximum likelihood estimation of slope stability

V. K. Singh and B. D. Baliga 55 Slope design of an open pit copper mine

P. C. Jha and R. K. S. Chouhan 71 Long range rockburst prediction: a seismological approach

Technical Notes
R. Badal 79 Controlled blasting in jointed rocks

B. D. Banerjee, A. K. Singh and P. C. Garg 85 Modelling inflow of methane from coal seams into longwall workings

R. Bhasin 87 Rock mass characterization for large caverns in India and Norway using a new method of recording and presenting engineering geological data

Geomechanics Abstracts 1A

NUMBER 2

Alcibíades Serrano and Claudio Olalla 93 Ultimate bearing capacity of rock masses

M. Mauldon 107 Intersection probabilities of impersistent joints

A. A. Fakhimi and C. Fairhurst 117 A model for the time-dependent behavior of rock

F. K. Boadu and L. T. Long 127 The fractal character of fracture spacing and RQD

Special Contribution
Z. T. Bieniawski 135 Reviving the mission of rock mechanics teaching in mining and civil engineering

Technical Notes
J. Litwiniszyn 143 The Gauss function and the phenomena of rock mass subsidence and displacements of granular media

J. F. Shao, D. Kondo and S. Ikogou 149 Stress-induced microcracking in rock and its influence on wellbore stability analysis

C. Xu and R. J. Fowell 157 Stress intensity factor evaluation for Cracked Chevron Notched Brazilian Disc specimens

L. Jing and O. Stephansson 163 Topological identification of block assemblages for jointed rock masses

L. Jing, E. Nordlund and O. Stephansson 173 A 3-D constitutive model for rock joints with anisotropic friction and stress dependency in shear stiffness

R. W. Zimmerman, L. R. Myer and N. G. W. Cook 179 Grain and void compression in fractured and porous rocks

Geomechanics Abstracts 61A

NUMBER 3

I. L. Lim, I. W. Johnston, S. K. Choi and J. N. Boland 185 Fracture testing of a soft rock with semi-circular specimens under three-point bending. Part 1—Mode I

I. L. Lim, I. W. Johnston, S. K. Choi and J. N. Boland 199 Fracture testing of a soft rock with semi-circular specimens under three-point bending. Part 2—Mixed-mode

Yii-Wen Pan and Zeng-Lin Huang 213 A model of the time-dependent interaction between rock and shotcrete support in a tunnel

P. Valkó and M. J. Economides 221 Propagation of hydraulically induced fractures—a continuum damage mechanics approach

Technical Notes

K. X. Hu and J. Kemeny 231 A fracture mechanics analysis of the effect of backfill on the stability of cut and fill mine workings

J. R Hearst and C. S. Lynch 243 Measurement of *in situ* strength using projectile penetration

V. Rudajev, J. Vilhelm and J. Kozák 253 Simulation of aftershock series

M. S. King, M. Andrea and M. Shams Khanshir 261 Velocity anisotropy of carboniferous mudstones

I. L. Lim, I. W. Johnston and S. K. Choi 265 Assessment of mixed-mode fracture toughness testing methods for rock

S. H. Chen and G. N. Pande 273 Rheological model and finite element analysis of jointed rock masses reinforced by passive, fully-grouted bolts

Geomechanics Abstracts 123A

NUMBER 4

C. M. Haberfield and I. W. Johnston 279 A mechanistically-based model for rough rock joints

Ernian Pan, Bernard Amadei and William Z. Savage 293 Gravitational stresses in long symmetric ridges and valleys in anisotropic rock

J. K. Kodikara and I. W. Johnston 313 Shear behaviour of irregular triangular rock–concrete joints

P. Lunardi, P. Froldi and E. Fornari 323 Rock mechanics investigations for rock slope stability assessment

O. Scotti and F. H. Cornet 347 *In situ* evidence for fluid-induced aseismic slip events along fault zones

H. Ito and N. Kumagai 359 A creep experiment on a large granite beam started in 1980

Technical Notes

Takashi Nishiyama and Hiromu Kusuda 369 Identification of pore spaces and microcracks using fluorescent resins

Jinhuo Liang and Ulf Lindblom 377 Critical pressure for gas storage in unlined rock caverns

Li Shiping, Li Yushou, Li Yi, Wu Zhenye and Zhou Gang 383 Permeability–strain equations corresponding to the complete stress–strain path of Yinzhuang sandstone

Geomechanics Abstracts 175A

NUMBER 5

J. Tronvoll and E. Fjær 393 Experimental study of sand production from perforation cavities

L. Schmitt, T. Forsans and F. J. Santarelli 411 Shale testing and capillary phenomena

T. Ünlü and D. J. Reddish 429 Multiple entry pillar stability assessment using the limit equilibrium method

T. D. Wiles and P. K. Kaiser 439 *In situ* stress determination using the under-excavation technique—I. Theory

T. D. Wiles and P. K. Kaiser 447 *In situ* stress determination using the under-excavation technique—II. Applications

D. R. McCreath and M. S. Diederichs 457 Assessment of near-field rock mass fracturing around a potential nuclear fuel waste repository in the Canadian Shield

W. Z. Savage 471 Gravity-induced stresses in finite slopes

G. Beer and B. A. Poulsen 485 Efficient numerical modelling of faulted rock using the boundary element method

R. Corthésy, M. H. Leite, G. He and D. E. Gill 507 The RPR method for the doorstopper technique: four or six stress components from one or two boreholes

P. Coquard and R. Boistelle 517 Water and solvent effects on the strength of set plaster

Hongliang He and T. J. Ahrens 525 Mechanical properties of shock-damaged rocks

International Society for Rock Mechanics. Commission on Swelling Rock **H. Einstein (Co-ordinator)** 535 Comments and recommendations on design and analysis procedures for structures in argillaceous swelling rock

International Society for Rock Mechanics. Commission on Swelling Rock **H. Einstein (Co-ordinator)** 547 Suggested methods for rapid field identification of swelling and slaking rocks

Technical Notes

S. J. D. Cox and R. H. T. Cox 551 A large, high-pressure, triaxial cell

W. G. Pariseau 555 On the significance of dimensionless failure criteria

S. J. Jung, K. Prisbrey and G. Wu 561 Prediction of rock hardness and drillability using acoustic emission signatures during indentation

Author's Reply
M. S. Bruno 569 Authors's Reply to Discussion by E. Detournay and T. J Boone regarding the paper "Pore pressure influence on tensile fracture propagation in sedimentary rock"

Geomechanics Abstracts 225A

NUMBER 6

R. J. Fowell and C. Xu 571 The use of the cracked Brazilian disc geometry for rock fracture investigations

D. F. Malan, J. A. L. Napier and B. P. Watson 581 Propagation of fractures from an interface in a Brazilian test specimen

Y. Wang and M. B. Dusseault 597 Stresses around a circular opening in an elastoplastic porous medium subjected to repeated hydraulic loading

N. Barton, T. L. By, P. Chryssanthakis, L. Tunbridge, J. Kristiansen, F. Løset, R. K. Bhasin, H. Westerdahl and G. Vik 617 Predicted and measured performance of the 62 m span Norwegian Olympic Ice Hockey Cavern at Gjøvik

C. D. Martin and N. A. Chandler 643 The progressive fracture of Lac du Bonnet granite

J. Bodziony, J. Krawczyk and J. Topolnicki 661 Determination of the porosity distribution in coal briquettes by measurements of the gas filtration parameters in an outburst pipe

X. Yi and P. K. Kaiser 671 Impact testing for rockbolt design in rockburst conditions

D. E. Gill, M. H. Leite and D. Labrie 687 Designing mine pillars with the convergence–confinement method

A. S. Paine and C. P. Please 699 An improved model of fracture propagation by gas during rock blasting—some analytical results

A.-P. Bois, G. Ballivy and K. Saleh 707 Monitoring stress changes in three dimensions using a solid cylindrical cell

B. Amadei and T. Illangasekare 719 A mathematical model for flow and solute transport in non-homogeneous rock fractures

Technical Notes
C. Butenuth, M. H. De Freitas, H.-D. Park, K. Schetelig, P. Van Lent and P. Grill 733 Observations on the use of the hoop test for measuring the tensile strength of anisotropic rock

A. J. Jupe 743 Confidence intervals for *in situ* stress measurements

Li Shihui 749 Application of rock mechanics principles to tunnelling in China

Geomechanics Abstracts 263A